INSERTING APPARATUS WITH CONTROLLED, MASTER CYCLE SPEED-DEPENDENT ACTUATOR OPERATIONS

AN APPLICATION FOR

UNITED STATES LETTERS PATENT

By

James R. Rivenbark

Raleigh, North Carolina

Keith A. Harshman

Apex, North Carolina

Frank J. Shinn

Fuquay-Varina, North Carolina

Bradford D. Henry

Cary, North Carolina

and

Steve W. McCay (Deceased)

"Express Mail" mailing number EF319341407US
Date of Deposit April 26, 2001
I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to the Commissioner for Patents, Washington, D.C. 20231
Shaylor E. Dunn

Description

INSERTING APPARATUS AND METHOD WITH CONTROLLED, MASTER CYCLE SPEED-DEPENDENT ACTUATOR OPERATIONS

Technical Field

The present invention is generally directed to an inserting apparatus and method, such as the type of apparatus and method useful in performing mail inserting operations in which an insert is inserted into an envelope for subsequent processing. More particularly, the present invention is directed to an inserting apparatus and method capable of adaptively controlling one or more actuated components in response to a change in the cycle speed of the apparatus.

Background Art

Mail insertion machines implementing continuous motion, or at least substantially continuous motion, have been developed in the past. A basic function of such machines is to establish a flow of inserts, such as documents or other sheet-type products, establish a flow of envelopes, and combine both flows into a single, common feed path. Once a given insert and a given envelope enter the common feed path, the insert must be inserted into the opened envelope at a common insertion point, after which point the stuffed envelope is transported downstream along a single output path for subsequent processing.

In the continuous motion-type insertion machine, an effort is made to increase throughput by reducing the number of times the feed path must be stopped and/or reducing the duration of the stoppage. This has been accomplished by transporting the inserts along the feed path at a higher speed than the envelopes, or by at least accelerating the inserts in relation to the envelopes, so that a given insert "overtakes" or catches up to its corresponding, aligned envelope and is completely inserted into the envelope with minimal stoppage of the flow of either the insert or the envelope along the feed path.

As will be appreciated by persons skilled in the art, the successful operation of the above-described mail insertion machine depends upon adequate synchronization of the various moving components involved in carrying out the insertion process. It is often desirable to change the overall speed of the machine, such as when differently-sized inserts and/or envelopes are to be processed, in which case steps must be taken to ensure all moving components are still synchronized at the different machine speed. For example, in U.S. Patent No. 3,423,900 to Orsinger, a continuous motion inserting machine is disclosed in which all moving components, such as the envelope feeding and insert feeding mechanisms, are entirely mechanically linked together. It can be appreciated that any change in the operating speed of such a machine would necessitate laborious mechanical adjustments of several components in order to preserve synchronization.

Even with the modern development of servo motors and motion controllers, satisfactory methods have not heretofore been developed for interfacing such modern control components with mail inserting machines for the purpose of maintaining synchronization in response to varied machine

speeds, particularly in the context of continuous motion-type inserting machines. Indeed, the use of modern machine components often exacerbates the problem of synchronization. This has been particularly observed in the case of modern, variable-speed, cyclical mail inserting machines. During the operation of such machines, the duration of time between certain events vary according to overall machine speed. These machines, however, contain both servo motor-driven components or assemblies and actuator-driven components. The respective operating speeds of the motor-driven components or assemblies can be easily controlled and varied by a motion controller. At the same time, however, the respective activation speeds of the actuator-driven components (i.e., the duration of time required for the component to move from its inactive or OFF state to its active or ON state) are inherently fixed and thus cannot be forced to vary. It can therefore be appreciated that the use of variable-speed components together with fixed-speed components renders synchronization difficult.

As an example, a variable-speed cyclical machine contains one or more rotating assemblies or components whose respective operating speeds somehow depend on the master speed of the machine (such as through actual linkage to the main drive shaft of the machine, or simply due to the requisite timing relation among the various moving components of the machine). If, for example, the machine is running at a machine speed of 1 cycle per second, the machine takes 250 milliseconds to move through 90 degrees of its machine cycle. If the speed of the machine is increased to 5 cycles per second, the machine now takes only 50 milliseconds to move through the same 90 degrees of the machine cycle at this new machine speed. As part of its operation, the machine can further contain at least one component driven by a solenoid. As a

general matter, solenoids take a constant duration of time to become active (e.g., the time required for the plunger of the solenoid to fully extend outwardly and actually cause the required actuation event), and this activation time is completely independent of the machine speed. In the present example, the solenoid takes 50 milliseconds to become active. The successful operation of this machine dictates that the solenoid be fully active at a given point in time during the machine cycle (e.g., 90 degrees). In addition, the operation requires that the solenoid be inactive until another given point during the cycle (e.g., 85 degrees). Accordingly, there exists no common point during any machine cycle at which the solenoid can be turned ON for all speeds over which the machine is intended to operate.

Continuing with the present example, at the machine rate of one cycle per second, the machine travels 18 degrees (90 degrees divided by 5) in 50 milliseconds (250 milliseconds divided by 5). At this rate, the solenoid must be activated, or fired, at 72 degrees (90 degrees minus 18 degrees) in order for the solenoid to be fully activated at 90 degrees. This is because, upon the initial energizing of this particular solenoid, it always takes 50 milliseconds for the solenoid to become completely active. In the present example, at 1 cycle per second, 50 milliseconds corresponds to 18 degrees of rotation through the machine cycle. As discussed above, at the machine rate of 5 cycles per second, the machine travels 90 degrees in 50 milliseconds. Hence, at this increased machine cycle speed, the solenoid must fire at 0 degrees in order to be fully activated at 90 degrees (because at 5 cycles per second, 50 milliseconds corresponds to 90 degrees, instead of 18 degrees in the case of a cycle speed of 1 cycle per second).

It can thus be seen that if the machine has been operating at 5 cycles per second and the solenoid is correctly set to fire at 0 degrees at that machine speed, the solenoid will fire at the wrong time if the machine speed is changed. In the specific example, if the machine speed is decreased to 1 cycle per second and the solenoid fires at 0 degrees, the solenoid will become fully active at 18 degrees, which is much too early during the machine cycle if the machine is running at 1 cycle per second. One the other hand, if the solenoid is set to fire correctly (at 72 degrees) while the machine speed is 1 cycle per second, and the machine is actually running at 5 cycles per second, then the solenoid will not be fired until the machine cycle reaches 72 degrees and thus will not be active until 162 degrees (72 degrees plus 90 degrees, where 90 degrees corresponds to the fixed activation time of the solenoid, 50 milliseconds, at the machine speed of 5 cycles per second), which is much too late.

In either scenario, the solenoid will fire, and thus eventually become fully active, at the wrong point in time during the operating cycle of the machine. In the context of a continuous motion inserting machine, as well as in other types of machines requiring coordination and synchronization of different moving components, the improper activation time of the solenoid could result in an insert or an envelope failing to be presented at the proper time into the feed path, an envelope failing to open, an insert failing to be completely inserted into an envelope prior to ejection to downstream processes, and so on.

One approach to maintaining proper control and synchronization in a variable-speed inserter machine is disclosed in the following series of related disclosures: U.S. Patent Numbers 5,823,521; 5,941,516; 5,949,687; 5,954,323; and 5,975,514; all of which issued to Emigh et al. and are owned by Bell &

Howell Mail and Messaging Technologies Co. In the main embodiment disclosed in these patents, a Phillipsburg-type mail inserter machine has twelve stations or subassemblies, all of which operate (i.e., are activated and deactivated) in timed relation over the 360-degree timing cycle of the inserter machine. The respective operations of these stations is put under computer-driven, adaptive control, in order to compensate for the electromechanical time lags exhibited by certain components such as pneumatic cylinders that require extension and retraction. As a result, the ON-OFF control signal used to initiate and terminate the respective electromechanical functions of the actuator-type components can be adjusted in response a change machine speed, thereby maintaining correct timing of the various components.

In the Emigh et al. patents, the adaptive control is implemented by programming "look-up" speed tables into the control software executed by the computer. These speed tables include the correct start angles (i.e., the timing for an ON control signal) and stop angles (i.e., the timing for an OFF control signal) for each station requiring such control. A "low" speed table, derived empirically, is provided for the machine operating within the range of 0 – 2000 cycles per hour. Additionally, the respective time lags (or activation times) for the various actuator-type components are empirically measured, and the resulting value stored in an "operational delay" look-up table. The values from the operational delay tables are used together with the cycle speed of the machine to calculate adaptive adjustment factors, which in turn are used in further calculations to determine new start and stop angles for a different cycle speed. These new values are entered into a new speed table. This process is carried out until five successive speed tables are generated, each corresponding

to a cycle speed range of 2,000 cycles per hour in width, such that the five speed tables cover the operation of the machine over a total range of 0 – 10,000 cycles per hour. The mail inserter machine is ready for operation only after all five predetermined speed tables have been stored in memory.

During operation of the mail inserter machine disclosed in the Emigh et al. patents, the computer samples the output of a tachometer such as an absolute optical encoder interfaced with the main drive shaft of the machine. This sampling is rigidly performed at constant intervals as dictated by a clock speed, regardless of what the machine is actually doing. In the specific embodiment disclosed, the sampling is taken without exception every 100 milliseconds. Based on the cycle speed measured by the encoder, the computer selects the appropriate speed table and uses the values from the selected speed table to determine the proper control signals to be issued to the actuator-type components. As an alternative, the computer can use the low speed table and the operational delay table to update a new speed table every 100 milliseconds. It is disclosed, however, that this latter method has the disadvantage of possibly slowing down the computer due to the CPU having to make repetitive calculations every 100 milliseconds.

It would be therefore be advantageous to provide a method and apparatus for more precisely controlling and adjusting actuators in response to variable machine speeds on a substantially continuous basis, particularly in the operating environment of continuous motion inserting machines, in order to more easily and precisely maintain synchronization after a speed adjustment occurs, and further to ensure more consistent performance during ramp-up and shut-down portions of the machine cycle.

Disclosure of the Invention

The present invention provides a method for controlling a machine that operates over a master cycle at variable cycle speeds, and that includes one or more assemblies which perform rotational movements in synchrony and in combination with one or more other actuated peripheral devices. The peripheral devices are activated by actuators such as solenoids known to exhibit generally constant time lags. Conventionally, such machines are not capable of operating at different cycle speeds, since such a change has in the past thrown the rotational assemblies out of synchronization with the peripheral devices. The method according to the present invention, however, has the advantageous feature of being able to make on-the-fly adjustments to solenoid timing in response to changing cycle speed, and thus efficiently maintain synchronization. This method is implemented by a motion controller or other suitable device capable of electronic processing of an instruction set for performing position-based velocity compensation. The method has been successfully demonstrated in the environment of a continuous motion inserting apparatus, such as the type employed in mail processing jobs, although it will be understood that the present invention will have application outside the immediate scope of the continuous motion inserting apparatus. The present invention can be implemented in mail inserting machines other than the continuous-motion type, as well as any machine requiring synchronization among rotational and actuated components.

According to one embodiment of the present invention, an inserting apparatus operable over a range of master cycle speeds comprises a master drive assembly, an encoder, an insert conveyor assembly, an envelope conveyor assembly, a first actuator, and a motion controller. The master drive assembly is

operative over a master cycle and at variable master cycle speeds. The encoder is operatively coupled to the master drive assembly, and is adapted to produce an encoder signal indicative of a current master cycle speed at which the master drive assembly is operating. The insert conveyor assembly is driven by a first motor at a variable insert conveyor speed. The envelope conveyor assembly is driven by a second motor at a variable envelope conveyor speed. During any master cycle, the insert conveyor assembly speed can be greater than the envelope conveyor assembly speed in order to implement continuous-motion inserting operations. The first actuator has a substantially constant activation time lag, and is disposed in actuating communication with a first peripheral device. The motion controller controls the insert conveyor assembly speed, the envelope conveyor assembly speed and an activation position of the first actuator based on the encoder signal. Accordingly, the motion controller electrically communicates with the encoder, the first motor, the second motor and the first actuator. Once during every master cycle, the motion controller calculates the first actuator activation position, and causes the first actuator to be activated at the calculated first actuator activation position.

According to another embodiment of the present invention, the inserting apparatus includes a computer program product comprising computer-executable instructions embodied in a computer-readable medium. The computer program product communicates with the motion controller and is adapted to, once during every master cycle, calculate the first actuator activation position and cause the first actuator to be activated at the calculated first actuator activation position.

According to yet another embodiment of the present invention, a method is provided for controlling an inserting apparatus over a range of master cycle speeds. The method encompasses monitoring a master cycle speed at which an inserting apparatus operates over a plurality of master cycles, and determining when a new master cycle has begun. Once during every master cycle of operation of the inserting apparatus, a first calculation is performed. The first calculation determines a first cyclical position of the new master cycle at which an actuated device should begin to be activated. The calculation is based on the master cycle speed measured for the new master cycle, a predetermined time duration required for the actuated device to become fully active, and a predetermined cyclical position of the new master cycle at which the actuated device should be fully active. The actuated device is caused to begin to be activated when the new master cycle reaches or exceeds the calculated first cyclical position.

According to still another embodiment of the present invention, the method also encompasses, once during every master cycle of operation of the inserting apparatus, performing a second calculation to determine a second cyclical position of the new master cycle at which an actuated device should begin to be deactivated. This calculation is based on the master cycle speed measured for the new master cycle, a predetermined time duration required for the actuated device to become inactive, and a predetermined cyclical position of the new master cycle at which the actuated device should be fully inactive. The actuated device is caused to become inactive when the new master cycle reaches or exceeds the calculated second cyclical position.

According to a further embodiment of the present invention, the method is implemented by a computer program product comprising computer-executable instructions embodied in a computer-readable medium.

According to a still further embodiment of the present invention, a method is provided for continuously inserting inserts into corresponding envelopes in a controlled manner, and over a range of master cycle speeds at which an inserting apparatus operates. The method encompasses monitoring a master cycle speed at which an inserting apparatus operates over a plurality of master cycles, and determining when a new master cycle has begun. Once during every master cycle of operation of the inserting apparatus, a first calculation is performed. The first calculation determines a first cyclical position of the new master cycle at which an actuated device should begin to be activated. The calculation is based on the master cycle speed measured for the new master cycle, a predetermined time duration required for the actuated device to become fully active, and a predetermined cyclical position of the new master cycle at which the actuated device should be fully active. The actuated device is caused to begin to be activated when the new master cycle reaches or exceeds the calculated first cyclical position. Activation of the actuated device assists in an inserting process performed by the inserting apparatus, such as by opening an envelope prior to insertion, registering an envelope, or transporting the stuffed envelope away at the correct point in time during the machine cycle.

The method further encompasses feeding an insert along a feed path at an insert feed rate in timed relation with the activation of the actuated device, and likewise feeding an envelope along the feed path at an envelope feed rate in timed relation with the activation of the actuated device. The insert feed rate is

greater than the envelope feed rate, so that the insert is caused to be inserted into the envelope, again in timed relation with the activation of the actuated device.

It is therefore an object of the present invention to provide an improved continuous motion inserting machine and an improved inserting method, wherein tight control and synchronization of the various moving components can be maintained over a wide range of machine speeds.

It is another object of the present invention to provide an inserting machine and related method that include a motion controller or other electronic processing device, which motion controller is capable of calculating in real time the correct cyclic positioning of certain actuated components during operation of the inserting machine, so that a change in machine speed will not require a reconfiguration of one of more machine components.

It is yet another object of the present invention to provide an inserting machine and related method that update the activation times of certain components every master rotation or master cycle of the inserting machine, such that the frequency of the updating process varies directly with the speed of the master cycle.

Some of the objects of the invention having been stated hereinabove, other objects will become evident as the description proceeds when taken in connection with the accompanying drawings as best described hereinbelow.

Brief Description of the Drawings

Figure 1 is a schematic diagram of an inserting apparatus according to the present invention;

Figure 2 is a flow diagram illustrating a control process performed during operation of the inserting apparatus shown in Figure 1;

Figure 3 is a top plan view of one embodiment of the inserting apparatus according to the present invention;

Figure 4 is a side elevation view of a portion of the inserting apparatus shown in Figure 3;

Figures 5A and 5B are perspective views of another embodiment of the inserting apparatus according to the present invention;

Figure 5C is a top plan view of the inserting apparatus shown in Figures 5A and 5B;

Figure 6 is a side elevation view of another portion of the inserting apparatus shown in Figure 3;

Figure 7A is a side elevation view of a portion of the inserting apparatus shown in Figures 5A and 5B;

Figure 7B is a side elevation view of another portion of the inserting apparatus shown in Figures 5A and 5B; and

Figure 8 is a side elevation view of a mail piece take-away device provided in accordance with the present invention.

Detailed Description of the Invention

Referring now to Figure 1, an inserting apparatus or system, generally designated **10**, is schematically illustrated. Inserting apparatus includes a master drive assembly **15** that typically drives a primary function such as the transport of inserts downstream to one or more assemblies associated with insertion apparatus **10**. Master drive assembly **15** includes a rotating component

(not specifically shown), such as a motor-driven drive shaft, which might be mechanically linked to other rotating components as understood by persons skilled in the art. An encoder **20** or similar device interfaces with the rotating component of master drive assembly **15**. Encoder **20** measures the rate at which master drive assembly **15** is physically rotating (i.e., the master cycle speed) in encoder pulses per second, and converts this measurement into an electrical output signal. The encoder signal is read and interpreted by a motion controller **C**, which includes an I/O interface, signal conditioning and amplification elements, and associated circuitry as understood by persons skilled in the art.

Inserting apparatus **10** further includes a number of assemblies (or subassemblies) necessary for implementing the continuous-motion inserting process. Accordingly, inserting apparatus **10** preferably includes at least an insert conveyor assembly, generally designated **30**, and an envelope conveyor assembly, generally designated **40**. Insert conveyor assembly **30** includes at least one rotating component that is controlled by a servo motor **32**. Likewise, envelope conveyor assembly **40** includes at least one rotating component controlled by a servo motor **42**. Each servo motor **32** and **42** electrically communicates with, and is thus controlled by, motion controller **C**. As described more fully hereinbelow, during any given machine (or operating) cycle of inserting apparatus **10**, and at any given master cycle speed, the speed at which insert conveyor assembly **30** operates is generally greater than the speed at which envelope conveyor assembly **40** operates. Motion controller **C** receives the output signal from encoder **20** and, based on this measured master cycle speed, determines the proper operating speeds for insert conveyor assembly **30**

and envelope conveyor assembly **40**, respectively, as well as start and stop times (if needed during the machine cycle) in order to maintain synchronization. It will be understood that other variable-speed assemblies could be provided as part of, or in combination with, inserting apparatus **10** and likewise be controlled by motion controller **C**. A user interface **UI** of a conventional form, such as a keyboard, can also be provided to enable the programming of motion controller **C**, the input of commands such as START, STOP and JOG, as well as the input of data such as solenoid timing characteristics and desired device activation positions (as described hereinbelow).

Inserting apparatus **10** also includes one or more actuator-operated, peripheral devices or components. Each actuated component is characterized by the fact that the component generally moves between an ON and an OFF state, or equivalently an operational and non-operational state, and further by the fact that a solenoid, pneumatic cylinder, hydraulic cylinder or other actuator is employed to cycle or reciprocate the actuated component between its ON and OFF states. Each actuator, which hereinafter will be referred to by the term "solenoid" in a non-limiting manner, has a fixed activation time as well as a fixed deactivation time. That is, once a control signal is sent to "fire" or energize the solenoid, the duration of time needed for the solenoid to be fully active (such as the time period required for a plunger arm to be extended fully outwardly in order to switch the actuated component into its ON state) is generally and inherently constant. In the same manner, once a control signal is sent to de-energize the solenoid (or in other equivalent cases, once the ON control signal is removed), the time needed for the solenoid to deactivate is also fixed.

In the present embodiment, three solenoid-actuated peripheral devices are illustrated: an envelope opening device, generally designated **O**; an envelope registration device, generally designated **R**; and a stuffed envelope take-away device, generally designated **TA**. Each solenoid-actuated device **O**, **R** and **TA** electrically communicates with, and is thus controlled by, motion controller **C**. In accordance with the present invention, while the activation/deactivation times of the respective solenoids associated with each device **O**, **R** and **TA** are fixed, their respective firing times and thus their respective fully activated times can vary in response to the master cycle speed read and interpreted by motion controller **C**.

Referring now to Figure 2, the basic process by which motion controller **C** controls the operation of actuated devices **O**, **R** and **TA**, as executed by either firmware or software associated with motion controller **C**, is illustrated. It will be understood that prior to initialization of the process, the timing characteristics of each solenoid involved will have been determined either through vendor information or testing. The basic process, which occurs once every machine cycle, can be represented by the following algorithm:

BEGIN LOOP

CALCULATE Position To Activate = Desired Activation Position – (Time To Activate x Current Speed Of Master)

WAIT for Current Position > or = Position to Activate

ACTIVATE device

CALCULATE Position to Deactivate = Desired Deactivation Position – (Time To Deactivate x Current Speed of Master)

WAIT for Current Position > or = Position To Deactivate

DEACTIVATE Device

WAIT for End Of Cycle

END LOOP

The various values used in the above algorithm are defined as follows:

Position To Activate = the actual cyclical position at which activation (i.e., firing of the solenoid) will begin to occur;

Desired Activation Position = the cyclical position at which activation should be completed (i.e., when the solenoid is fully active);

Time To Activate = the real time taken for the device to become active (i.e., the generally constant time lag inherent in the device for activation);

Current Speed Of Master = the speed of the master cycle at the time measured;

Current Position = the current position of the master cycle;

Position to Deactivate = the actual cyclical position at which deactivation (e.g., the start of a retraction movement) will begin to occur;

Desired Deactivation Position = the cyclical position at which deactivation should be completed (e.g., full retraction);

Time To Deactivate = the real time taken for the device to become deactivated (i.e., the generally constant time lag inherent in the device for deactivation); and

End Of Cycle = a flag or counter denoting that one cycle has passed.

It will be noted that the values for the Desired Activation Position and the Desired Deactivation Position are predetermined by the operator or the programmer of inserting apparatus **10**. These values, like those of the

corresponding solenoid time lags (Time To Activate and Time To Deactivate), are "absolute" in the sense that they are independent of the Master Speed Of Cycle. For instance, it might be predetermined that a peripheral device **O**, **R** or **TA** must be switched to its operative state at 90 degrees during every machine cycle, in order for its operation to be properly synchronized with other operations performed by inserting apparatus **10**. For a given mail inserting job and/or a given insert and envelope size, this criterion will not change. However, the rotational position or angle relative to the machine cycle at which the corresponding solenoid must be fired so that peripheral device **O**, **R** or **TA** becomes fully active at 90 degrees will vary with the speed of the machine cycle. Thus, the above-described control process is used to make the necessary adjustments in response to a changed cycle speed.

Referring now to the flow diagram of Figure 2, the control process performed by motion controller **C** for each actuated device **O**, **R** and **TA** is further described. At step **51**, inserter apparatus **10** (or master drive assembly **15** thereof) begins to rotate, and motion controller **C** receives an output signal from encoder **20** (see Figure 1). Once inserting apparatus **10** is powered up at starting step **51**, at step **53**, using the cycle speed (Current Speed Of Master) read by encoder **20** and the time lag information (Time To Activate) indexed to the particular actuated device **O**, **R** or **TA** to be controlled, motion controller **C** determines the proper point in time during the current machine cycle at which to fire the corresponding solenoid (Position To Activate). At step **55**, motion controller **C** waits for the current rotational position of the master cycle (Current Position) to at least reach the calculated Position to Activate the solenoid. Motion controller **C** can do this by counting output pulses from encoder **20** that

identify the current rotational position of inserter apparatus **10** along its machine cycle. At step **57**, as soon as motion controller **C** determines that the Current Position equals or exceeds the calculated Position To Activate, motion controller **C** sends a control signal or takes some other appropriate step to cause the solenoid to fire. In this manner, solenoid will activate its associated device **O, R** or **TA** at the proper rotational position of the machine cycle, in synchronization with the respective operations of insert conveyor assembly **30** and envelope conveyor assembly **40** (see Figure 1).

Continuing to step **59**, motion controller **C** then uses the cycle speed (Current Speed Of Master) previously received from encoder **20**, as well as the time lag information (Time To Deactivate) indexed to actuated device **O, R** or **TA**, to determine the proper point in time during the current machine cycle at which to deactivate the solenoid (Position To Deactivate). At step **61**, motion controller **C** waits for the current rotational position of the master cycle (Current Position) to at least reach the calculated Position to Deactivate the solenoid. At step **63**, as soon as motion controller **C** determines that the Current Position equals or exceeds the calculated Position To Deactivate, motion controller **C** sends a control signal or takes some other appropriate step to cause the solenoid to become de-energized. In this manner, solenoid will de-activate its associated device **O, R** or **TA** at the proper rotational position of the machine cycle, in synchronization with the respective operations of insert conveyor assembly **30** and envelope conveyor assembly **40**. Moreover, actuated device **O, R** or **TA** will remain deactivated until the proper time for re-activation, so as not to interfere with the respective operations of insert conveyor assembly **30** and envelope conveyor assembly **40**. Finally, at step **65**, motion controller **C**

waits for the occurrence of the End Of Cycle to be flagged, after which it begins the next control sequence as described above.

It will be noted that, because motion controller **C** executes its control process once every machine cycle, the frequency by which motion controller **C** executes the control process, for any given actuated device, varies directly with the speed of the machine cycle. Hence, motion controller **C** carries out a true real-time, "on-the-fly" control process that does not lag behind the machine cycle. At the same time, however, one complete machine cycle of inserting apparatus **10** can virtually always be expected to last longer than 100 milliseconds. Accordingly, any CPU or other electronic processor associated with motion controller **C**, having moderate processing speed, should not be detrimentally affected by execution of this control process. It will be further noted that motion controller **C** makes its adjustments to the respective activation and deactivation cyclic positions of all peripheral devices **O**, **R** and **TA** involved, without the need for manual adjustments by an operator of inserting apparatus **10**.

Referring now to Figures 3 - 8, exemplary embodiments are illustrated for continuous motion inserting apparatus **10**. In accordance with the present invention, inserting apparatus **10** is advantageously controlled by motion controller **C**, which is programmed to implement the control process described hereinabove. As described previously, inserting apparatus **10** comprises insert conveyor assembly **30** and envelope conveyor assembly **40**. Both insert conveyor assembly **30** and envelope conveyor assembly **40** are servo motor-controlled mechanisms and operate to continuously feed their respective products, i.e., inserts **I** and envelopes **E** in a feed direction **F** without stopping for

any substantial amount of time. During this feeding process, as will be described below, insert conveyor assembly **30** and envelope conveyor assembly **40** cooperate to place an insert **I** within a corresponding envelope **E**.

As shown in Figures 3 and 4, insert feed conveyor assembly **30** includes side-by-side chain (or, alternatively, belt) conveyors in which each chain **71** and **71'** is wrapped around one or more pairs of rotatable sprockets **73A** and **73B**, respectively. To drive each chain **71** and **71'**, it is preferred to fixedly mount an adjacent pair of sprockets **73B** on common drive shaft **75** and then connect drive shaft **75** to servo motor **32** by a mechanical movement **77**, such as a conventional belt and pulley combination. It is also possible to mount each sprocket **73A** on its own axle and then connect each axle to its own servo motor **32**. In either form, however, servo motor(s) **32** electrically communicates with, and thus is controlled by, motion controller **C** as described hereinabove. In addition, tension sprockets **79** take up any slack in chains **71** and **71'** and therefore control the tension in chains **71** and **71'**. Finally, each chain **71** and **71'** has a plurality of insert transport elements such as pusher fingers **81**, **81'**, **83**, **83'**, **85** and **85'**, attached thereto. These pusher fingers **81**, **81'**, **83**, **83'**, **85** and **85'** operate to push insert **I** downstream in feed direction **F** and at a continuous and constant speed. As shown in the alternative embodiment of Figures 5A – 5C, additional pusher fingers, such as pusher fingers **82**, **82'**, **84** and **84'**, can be provided to handle a greater number of inserts **I** along feed direction **F**. As also best shown in Figure 5A, additional pairs of sprockets **73A** and **73B** and tension sprockets **79** can be provided if desired.

As best shown in Figure 3, envelope conveyor assembly **40** preferably includes a pair of envelope transport conveyor subassemblies, generally

designated **110** and **110'**, which are essentially mirror images of each other and cooperate to transport envelopes **E** downstream in feed direction **F** at a constant speed, with only momentary stopping during a registration step. Each envelope transport conveyor subassembly **110** and **110'** is also preferably a chain (or belt) mechanism, like those that make up insert conveyor assembly **30**. Chains **112** and **112'** are wrapped around rotatable sprockets **114**, **116** and **114'**, **116'**, respectively. Sprockets **116** and **116'** of each of envelope transport conveyor subassemblies **110** and **110'** are respectively connected to servo motors **42** and **42'** through a mechanical movement **118** and **118'**, such as a conventional belt and pulley system. It is also possible to commonly drive envelope transport conveyor subassemblies **110** and **110'** by a common servo motor **42** and associated drive assembly **43**, as shown in Figures 5A - 5C. In either case, like servo motor **32**, servo motors **42** and **42'** are electrically connected to, and thus controlled by, motion controller **C**.

For transporting envelopes **E** along feed path **F**, each envelope transport conveyor chain **112** and **112'** is provided with a plurality of envelope control elements or opening fingers **121**, **121'**, **123**, **123'**, **125** and **125'** that work together in opposing pairs. Additional pairs of opening fingers can be provided in order to handle a greater number of envelopes **E** along feed path **F**, such as the pair of opening fingers **122** and **122'** shown in Figures 5A – 5C. Each opening finger **121**, **121'**, **123**, **123'**, **125** and **125'** may be similarly constructed from suitably formed sheet metal or plastic in an elongated channel-shaped cross-section having its forward end shaped and constructed, i.e., tapered, to facilitate entry into the mouth of an envelope **E**. Opening fingers **121**, **121'**, **123**,

123', **125** and **125'** continuously travel along the paths defined by chains **112** and **112'** in the direction of arrows **H** and at a constant speed.

In the embodiment shown in Figure 5C, it can be seen that feed path **F** is longer between the general areas where an envelope **E** is presented, opened, filled with an insert **I** and taken away, as compared with the embodiment shown in Figure 3. The longer feed path **F** in Figure 5C permits more than one pair of envelopes **E** and inserts **I** to be processed at the same time during the operation of inserting apparatus **10**. For example, one envelope **E** can be opened at the same time as an insert **I** is being inserted into another envelope **E** or as a filled envelope **E** is being taken away, while another intermediate pair of envelopes **E** and inserts **I** are being transported from the presentation or registration point to the filling point. Hence, in one specific example of the embodiment shown in Figure 5A, just over two complete machine cycles will have transpired from the time that an envelope **E** is fed to the transport plane for registration to the time that the same envelope **E** is filled with an insert **I**. In other embodiments of inserting apparatus **10** having shorter feed paths **F**, only one envelope **E** is transported over the transport plane during any given machine cycle.

Figure 6 is an elevation view depicting the presentation, registration and opening of an envelope **E**. Envelopes **E** are fed to envelope transport conveyor subassemblies **110** and **110'** from an envelope feed assembly, generally designated **150**, a portion of which is illustrated in Figure 6, in the feed direction represented by arrow **G**. Envelope feed assembly **150** can include, for example, a conventional rotating, vacuum-operated envelope drum **151** having an envelope gripping member **153** thereon and positioned below a table surface **T**. Table surface **T** has a slot therein so that envelopes **E** can be fed by envelope

drum **110** from a position below table surface **T** to a position above table surface **T** so that each envelope **E** can be registered, opened, and stuffed.

To register envelope **E** in the registration area, registration mechanism generally designated **R** is used. Registration mechanism **R**, preferably in the form of a front edge registration system, includes retractable lower portion, generally designated **161**, and stationary upper portion, generally designated **163**. Stationary upper portion **163** comprises a plurality of spaced apart vertical plates **163A**. Retractable lower portion **161** comprises a moveable front stop **165** that is activated by an actuator for rotation along an arcuate direction indicated by arrow **J**. In the present embodiment, front stop **165** is attached through a suitable mechanical linkage **167** to a motor **169** that serves as the actuator. Mechanical linkage **167** converts the rotary motion of motor **169** into the reciprocating motion of front stop **165**. However, any type of motor and any type of linkage may be used so long as stop **165** can be moved above or below table surface **T**. As in the case of other actuator-type components described herein, this motor **169** electrically communicates with, and is thus controlled by, motion controller **C**.

When in its raised position, stop **165** interacts with vertical plates **163A** to form a gate that prevents envelopes **E** from passing through. This gate also forms a front registration element. Therefore, as envelope **E** is fed into the registration by envelope gripping member **153** of envelope drum **151**, its leading edge will be brought into contact with registration elements **161** and **163**, thereby registering and squaring envelope **E**. Envelope **E** is momentarily stopped at this time.

Referring to Figures 7A and 7B, an additional embodiment of inserting apparatus **10** is shown to include an alternative form of envelope registration mechanism **R**. In this embodiment, envelope registration mechanism **R** is activated by a solenoid-type actuator **180**. Again, actuator **180** electrically communicates with, and is thus controlled by, motion controller **C**.

Because envelope **E** is momentarily stopped in inserting apparatus **10** according to the invention, inserting apparatus **10** might not be characterized as being a true continuous inserting apparatus. However, this stop time (dwell) is both short in an absolute sense as well as in relation to the overall apparatus cycling time. For example, in one specific embodiment of inserting apparatus **10**, inserting apparatus **10** operates between 4,000 envelopes per hour and 25,000 envelopes per hour. In this example, the dwell time corresponding to the lower limit speed of 4,000 envelopes per hour is 106 milliseconds, and the dwell time corresponding to the higher limit speed of 25,000 envelopes per hour is 40 milliseconds. Generally, the dwell time will be less than 1 second. Furthermore, in inserting apparatus **10** according to the present invention, both envelope **E** and insert **I** are in motion during the entire inserting step. In a conventional incremental inserter, not only is the stop time (dwell) much longer both in absolute and relative terms, but the envelope is stationary during the entire inserting step. Accordingly, despite the small stop (dwell) time in inserting apparatus **10** according to the invention, inserting apparatus **10** still better approximates the operation of a true continuous motion inserting apparatus and therefore can be labeled as such.

Referring back to Figure 6, after envelope **E** is stopped, squared and registered, envelope **E** is opened by envelope opening mechanism, generally

designated **O**. Typically, envelope opening mechanism **O** includes some type of vertically movable vacuum element that is able to pull apart the walls of envelope **E**. In addition, envelope opening mechanism **O** includes a solenoid or other actuator to cause envelope opening mechanism **O** to reciprocate along the direction indicated by arrow **K**. Envelope opening mechanism **O** electrically communicates with, and is thus controlled by, motion controller **C**. After envelope **E** is opened, stop **165** is lowered to its position below table surface **T** and envelope transport conveyor subassemblies **110** and **110'** take over the feeding of envelope **E**.

Accordingly, referring back to Figure 3, a pair of opposing opening fingers **123** and **123'** will swing around sprockets **114** and **114'**, and begin to enter the gap of the mouth of opened envelope **E** along the opposite edges of envelope **E**. As opening fingers **123** and **123'** continue to move in feed direction **F**, they will continue entering envelope **E** until fully inside. By that point, opening fingers **123** and **123'** will have complete control of envelope **E**, feeding it downstream again as all opening fingers **121**, **121'**, **123**, **123'**, **125** and **125'** move downstream. Although envelope **E** was momentarily stopped from being fed, as described above, this time period is small in absolute terms as well as in relation to the inserter cycle speed that it results in a minimal delay, unlike the substantial delays incurred in prior art non-continuous (incremental) motion inserting apparatuses. Within engaged envelope **E**, opening fingers **123** and **123'** provide, in effect, an insert receiving funnel opening rearward. To facilitate reception of inserts **I** into the funnel thus provided, opening fingers **121**, **121'**, **123**, **123'**, **125** and **125'** are preferably provided on their lower rear portions with

flanges which can extend into close proximity of each other over the envelope flap (to hold the flap open).

As each envelope **E** is thus readied in the filling or stuffing zone, generally indicated at **200**, inserts **I** are thrust by insert conveyor assembly **30** through opening fingers **121**, **121'**, **123**, **123'**, **125** and **125'** and into envelopes **E**. The speed of insert conveyor assembly **30** is set to a speed faster than that by which envelopes **E** are fed downstream in direction **F** by envelope transport conveyor assembly **40**. Thus, inserts **I** will completely be inserted into envelopes **E**. It thus can be seen that each envelope **E** is moved in a downstream direction as envelope **E** is being filled, i.e., during the insertion step. Other than during the short moment taken by the registration step, each envelope **E** is continuously moving downstream and is not stationary. After envelope **E** has been filled, envelope **E** is transported away from inserting apparatus **10** to any further downstream stations that might be provided.

Referring to Figure 8, an exemplary mail piece take-away device, generally designated **TA**, is illustrated. Take-away device **TA** is typically disposed above or immediately downstream of filling zone **200** (see Figure 3). Take-away device **TA** generally includes a reciprocating element **211** and a roller **213**. Reciprocating element **211** has or is attached to a solenoid or equivalent actuator, to enable reciprocating element **211** to travel upwardly and downwardly along the direction indicated by arrow **L**. Take-away device **TA** electrically communicates with, and is thus controlled by, motion controller **C**. Accordingly, motion controller **C** causes the actuator of take-away device **TA** to urge reciprocating element **211** downwardly until roller **213** contacts stuffed envelope **E**. At this point, envelope **E** bears down on a take-away conveyor assembly **215**,

which could be a moving belt as illustrated or could be a driven roller assembly, and consequently is transported along feed direction F to downstream locations.

It is therefore seen from the above description that the present invention provides an apparatus, and a method for controlling the same, in which peripheral devices exhibiting generally constant time lags during activation are precisely and adaptively timed, during each master cycle, in relation to the various rotational assemblies constituting the apparatus, in response to an increase or decrease in the operational speed of the apparatus. As a result, synchronization can be effectively maintained throughout a wide range of operating speeds, thereby enhancing the functional flexibility and accuracy of the apparatus.

It will be understood that various details of the invention may be changed without departing from the scope of the invention. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation—the invention being defined by the claims.